Summary Report
of the
Workshop on

Space Biology on the Early International Space Station

Held at NASA Ames Research Center
Moffett Field, CA
March 14-15, 2002

Chaired by Nobel Laureate Dr. Baruch S. Blumberg
Director, NASA ARC Astrobiology Institute
and Dr. Kenneth M. Baldwin
University of California, Irvine
Chair, NASA Biological and Physical Research Advisory Committee

Sponsored by Dr. Maurice M. Averner
Program Manager
NASA Fundamental Space Biology Program

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Contents

Introduction

The Space Biology on the Early International Space Station Workshop was held at NASA Ames Research Center, Moffett Field, California, March 14-15, 2002. The purpose of the Workshop was to explore the type, scope and value of biological research that can be conducted over the next five years within the accommodations and constraints of the Space Shuttle/Space Station system, using available flight research instruments and new biotechnology assets.

The *Space Biology on the Early International Space Station* Workshop was sponsored by NASA's Fundamental Space Biology Program. The Workshop was co-chaired by Nobel Laureate Dr. Baruch S. Blumberg, Director of the Astrobiology Institute and Dr. Kenneth M. Baldwin, Professor of Physiology and Biophysics, University of California, Irvine, and Chair of the Biological and Physical Research Advisory Committee (BPRAC), which provides advice to the NASA Office of Biological and Physical Research (OBPR).

The Workshop brought together scientists expert in contemporary biology research approaches to explore new discovery areas; space flight instrument developers and technologists to examine hardware options; biotechnologists and bioinformatics specialists to investigate ways to amplify the scientific yield; and NASA space flight experts and program managers responsible for research implementation on the Space Shuttle/Space Station system to identify policy enablers and impediments. In addition, Workshop participants included economists such as eminent strategists Alvin and Heidi Toffler, political scientists, and commercialization experts. This "one stop shopping" approach allowed critical issues to be discussed and resolved within the workshop forum so that consensus recommendations could be implemented efficiently. The output of these deliberations is presented in this report.

The Executive Summary includes the general conclusions and recommendations that emerged from the entire workshop. A complete report is in preparation.

Executive Summary

Overview of Findings

What space offers to biological science. Space biology is the study of the only life that we know in its first generations beyond the planet of origin. The space environment is evolutionarily novel. It is characterized by significant differences, compared to Earth, in gravitational force, magnetic fields, and radiation fluxes. During life's evolution on Earth, gravity was one of the very few physical forces that did not change, so the emergence of life into the microgravity of space is of primary interest. The Space Station environment is characterized by a three to six order of magnitude reduction in one of the fundamental organizing forces of evolution. The last time an environmental change of this magnitude was encountered by terrestrial life was when the first organisms emerged from the sea to the land. As scientists have learned from the study of extreme environments on Earth, novel environments reveal novel biologies. The extreme hypogravity of the space environment offers the opportunity to discover features of terrestrial life that literally cannot be seen on Earth and to scientifically document one of the great evolutionary transitions of all time with all the tools of the biotech revolution.

What space biology research offers to NASA and the public. Space biology research also allows us to determine whether life from Earth is biologically bound to this world and to characterize the biological costs and opportunities in extended habitation and evolution beyond the planet of origin. This information is fundamentally important to removing the biological barriers to human expeditions beyond low Earth orbit. The space environment also opens new discovery domains for medical, environmental and commercial applications. Just as biotech companies aggressively study life in extreme environments on Earth to discover new biological solutions to difficult medical, environmental, and agricultural problems, the investigation of life in space has a history of similar applications in the past, and the potential for even more important applications in the future.

The importance of Space Station to space biology research. To conduct space biology research, three conditions must be met. The first is sufficient duration to carry out multiple generation studies. The second is sufficient sophistication to enable the right type of habitats, inflight manipulations and controls, and increasingly capable biotechnology applications. The third is the knowledge base on Earth to interpret the findings. Mir had the duration, but not the sophistication. The Space Shuttle had the sophistication but not the duration. Skylab had both the duration and the sophistication, but the biotech and infotech revolutions had not yet occurred, so the knowledge base was not sufficient to enable meaningful research on the most important issues in space biology. When complete, the International Space Station will meet all three conditions. The question addressed in this workshop is what important work can be done between now and Station “core complete.”

Early Space Station realities. The transition of the Space Shuttle from research to International Space Station (ISS) construction and the current projected 6-year delay in completion and launch of ISS core elements (2002 to 2008) presents a major challenge to the vitality of the international space biology research community. These designated "core complete" elements have also been reduced in scope due to budget constraints and will include a research centrifuge with reduced habitat capacity (from 8 to 4) and reductions in habitat funding to an incubator for simple organisms (NASA) and insect (Canadian Space Agency (CSA) habitat. During this period, the crew will be reduced by half (6 to 3) thus reducing crew involvement in experiment manipulations to near zero.

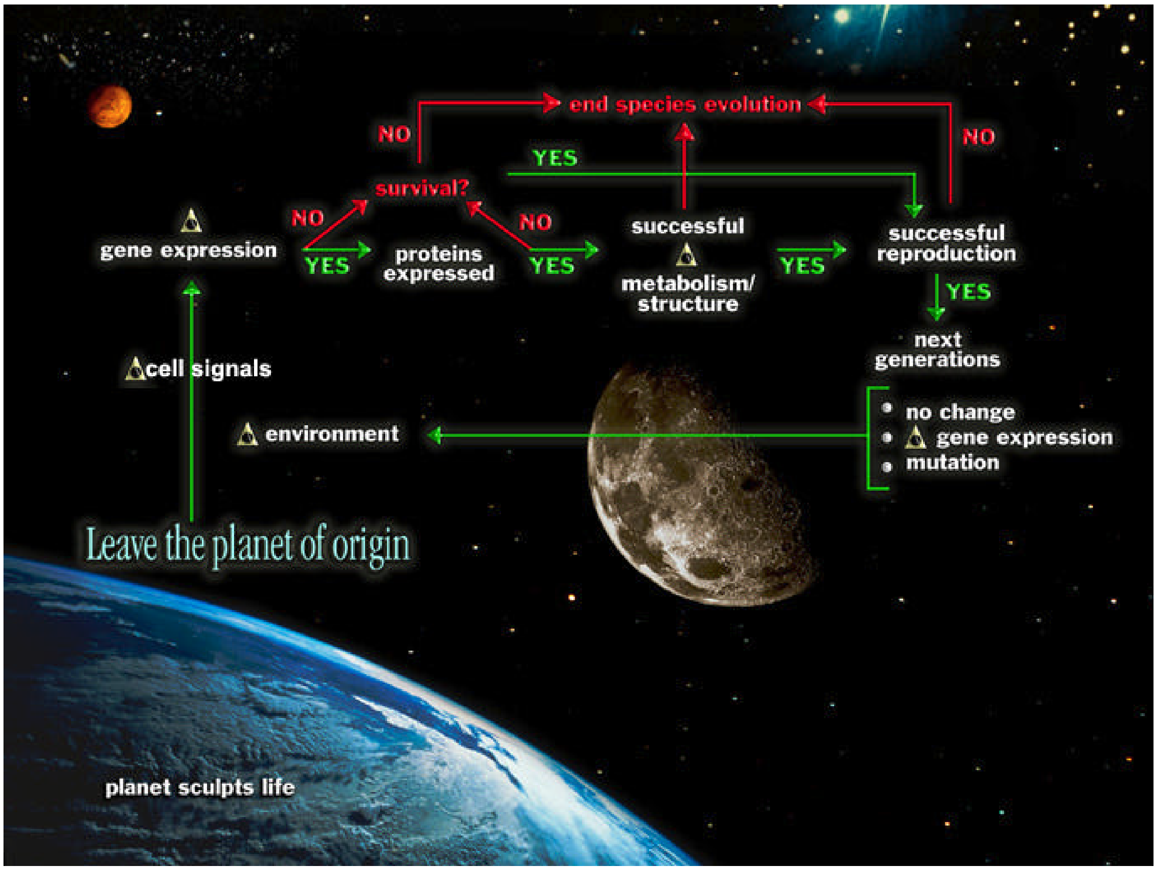
The challenge. It is essential for NASA and its international partners to find innovative but effective ways to conduct high-priority, high-quality space biology research during this period of reduced resources both to accelerate return on a skeptical public's investment and to keep the research community motivated and involved in space biosciences research. The solution to both challenges is through frequent flight investigations that also offer opportunities for continued discovery after the flight experiment is completed. To achieve such goals, NASA must be flexible enough to adapt its plans to work within the realities of the Space Shuttle/Space Station system and agile enough to take advantage of the opportunities offered by rapidly improving new technologies.

New solutions. Three convergent technological revolutions – in biotechnology, information technologies, and miniaturized systems – have recently opened previously inaccessible domains for biological discovery on Earth as well as in space. The resulting capability provides NASA with the means to amplify the value of a biosciences payload pound by many orders of magnitude, revealing previously unattainable biological information with unprecedented clarity and scope. New biotechnologies enable groundbreaking scientific discoveries from automated systems that use very small samples. These are the attributes needed for biological research under the constraints of the early Space Station system. In addition, some of the most interesting initial model systems can be maintained indefinitely in a dormant state, making them tolerant of launch delays, indifferent to launch stresses, and amenable to waiting for a convenient time on-orbit for experiment initiation.

Recommended strategy. Ultimately, most biological problems must be addressed at the cell level, but must be integrated and demonstrated at the organism level. The research strategy endorsed by workshop participants follows a central recommendation of the National Academy of Sciences Space Studies Board: "The present report… calls for an integrated, multidisciplinary approach that encompasses all levels of biological organization—the molecule, the cell, the organ system, and the whole organism—and employs the full range of modern experimental approaches from molecular and cellular biology to organismic physiology." (See: http://www.nas.edu/ssb/csbmmenu.htm Executive Summary). The overall concept is to follow this strategy approximately in the order presented. During the early Space Station, when resources are limited, groundbreaking studies can focus on molecular biology, cell and tissue biology, small model organisms that pioneered the Human Genome Project, the ecology of the Space Station and cell and molecular biology studies on flight crews. As Station resources mature, these pioneering investigations will be replaced by increasingly sophisticated research that involves more complex organisms, more and better *in situ* analyses, studies over longer life spans, better control systems (including a variable gravity centrifuge) and ultimately, multiple generation research. The recommendation is to start small and simple and build in sophistication and complexity over time.

Workshop Goals

The primary goal of the workshop was to determine what science questions and research approaches could be addressed using the current international inventory of flight and ground-based hardware and operating within projected Shuttle and ISS constraints.



III. Conclusions

A. Significant Fundamental Space Biology research can be performed on the International Space Station over the next five years. ISS research limitations and constraints over the next few years make studies of vertebrate adaptation to the space environment unlikely. However, valuable, even pioneering, research can be done on the Shuttle in conjunction with the ISS by using newly available biotechnology tools, miniaturized sensor and data systems, and existing integrated flight hardware to support studies at the molecular, cellular, and simple organism levels. The early ISS will provide opportunities for observation of phenomenon that were not previously observable from which hypotheses for further experiments can be generated. This interim research will build new expertise for conduct of molecular biology studies in space to complement future more comprehensive research with higher organisms and large centrifuges on the completed ISS.

B. Begin now. Molecular biology research opens new and fundamentally important discovery domains, allows the use of simple organisms and available automated hardware systems, requires minimal crew time and can be implemented with modest funding. Correlative studies involving genomic, proteomic, metabolic, and structural analyses using simple model organisms that pioneered the Human Genome Project will provide a wide range of new discovery opportunities for space biology research that were impossible to obtain five years ago. These techniques will be as important to space biosciences as they are to terrestrial biosciences.

C. Hardware to support these studies is available now from NASA, its international partners, NASA-sponsored Commercial Space Centers (CSC), and commercial vendors. No one group holds the full set of research instruments needed for success. Collaboration among these entities is essential to optimize access to and utilization of all hardware candidates. In addition, the biotechnology, information technology, and microminiaturization revolutions are still accelerating rapidly with new products appearing daily that further increase science yield and value. NASA must continually monitor progress in these areas and use them effectively to assure maximum value from its missions by leveraging billions of dollars of external investments. In addition, investments that increase inflight automation are strongly urged under the assumption that there will never be enough crew time.

D. Initial research objectives are to determine the basic mechanisms and metabolic pathways for microgravity and radiation effects on the molecular biology and evolution of simple living systems. See Figure 1. It has been demonstrated in space that data from each step outlined in figure 1 can be obtained using available flight qualified research instruments. With this approach, it is now possible to determine the sequence of molecular events that underlies life’s adaptation to space, readaptation to Earth, and response to countermeasures. Such measurements also allow researchers to compare space results to medical, environmental, and agricultural problems on Earth and confirm or refute concepts that certain terrestrial problems can benefit from insights obtained from space research.

The approach requires phasing research to match spacecraft accommodations. Beginning now, when Station facilities are most constrained, productive investigations can focus on the simplest biological models and most basic measurements that will form the foundation for all space biology research. As Station facilities mature, focus will shift to increasingly complex organisms, including humans and other mammals, and increasingly sophisticated inflight measurements and postflight analyses. All information will be captured computationally and used to generate increasingly complete models of how life adapts to the evolutionarily novel environment of space. Use of inflight, built-in small centrifuges and ground hyper-g centrifuges and Rotating Wall Vessels can complement the on-orbit microgravity studies and determine which biochemical events occur directly as a result of microgravity and which occur indirectly from other environmental variables, including shear, turbulence, and radiation.

This general strategy and its mission benefits are outlined in Figure 2 and implements the National Academy of Sciences Space Studies Board recommendation to investigate life at all levels of biological organization with all the tools of contemporary science.

It is important to note that the value of space biology research using more complex organisms is similarly amplified by the biotech revolution. Molecular biology research does not replace whole organism studies: it amplifies them.

E. The "new biology" allows the conduct of high-priority basic research with extensive sharing of tissues, cloning and other forms of data amplification that increase the science value of each payload pound. The ability to fly many very small organisms, use hardware with multiple experiment modules, clone DNA products, and use government and commercial bioinformatics tools for online data analysis can provide data to share among many investigators. It also provides the means to achieve statistical significance, independent confirmation of results, and other benefits that increase confidence in space biology data. Cell biology research may also be able to model a number of the ailments that afflict chronic exposure to hypogravity and cosmic radiation (e.g., immune dysfunction, renal tubular defects, bone marrow changes, mutations, etc.) and opportunities to pursue this should be maximized during the early phase of access to ISS.

Through this research, NASA will add a unique wing to the rapidly growing global library of bio-data. In the process there will be a biological recording for history of the transition of Earth life to space. The anticipated and actual benefits emerging from this research need to be communicated to decision-makers and the public in an understandable manner.

F. Some small payload potential flight opportunities exist now and more may be available soon. It is possible that experiments proposed within two months could fly on missions of opportunity in 2003. Flight qualified cell culture hardware is immediately available for both the Shuttle middeck and the Space Station. Each instrument contains several sample containers, each of which can hold a dedicated experiment, piggyback investigations that use only part of a sample or instrument volume, or multiple partial investigations. A program analogous to the "Minuteman" approach used by NASA's commercial program is strongly advised. Sample preservation is the biggest challenge in this scenario and workshop members strongly urge NASA to develop adequate cryopreservation techniques and recovery strategies that minimize launch and recovery artifacts. Another opportunity that begins in 2003 is the ability to fly small autonomous investigations on mini free flyer satellites in a type of “Bioexplorer” program. This can be done now during the construction phase. New flight hardware will be available in the 2004 timeframe that may accommodate additional molecular biology research requirements. An Extended Duration Orbiter, if it becomes available, would facilitate a 21-day mission and offer important opportunities for research until more resources are available on ISS.

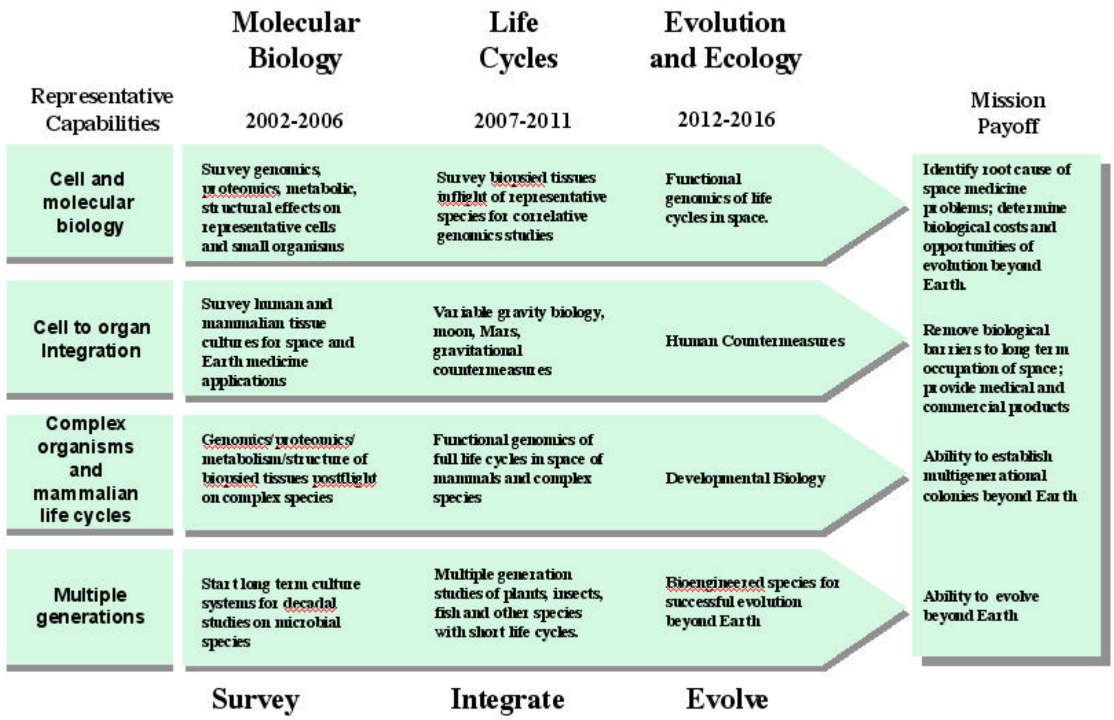


Figure 2. Phasing Strategy for Fundamental Space Biology on Space Station

III. Recommendations

Workshop recommendations were developed within four general categories: programmatics, science, technology, and societal benefits. Top-level recommendations are listed below.

The overall strategy is to consistent with the following recommendation from the 1998 Space Studies Board *Strategy for Space Biology and Medicine in the Next Century*: "The present report ... calls for an integrated, multidisciplinary approach that encompasses all levels of biological organization—the molecule, the cell, the organ system, and the whole organism—and employs the full range of modern experimental approaches from molecular and cellular biology to organismic physiology."

There is some urgency in implementing these investigations. Early Station biology studies would focus on fundamental issues and simple organisms. Such studies are not only foundational to understanding more complex issues, they also fit within the current vehicle constraints. These necessary fundamental investigations should be completed by 2005-2007 to yield critical inflight resources to the more complex and medically relevant studies of mammals and to the multigenerational studies that are crucial to understanding evolutionary processes.

A. Programmatics

How can NASA facilitate fundamental biology research onboard the early ISS?

1. Collaborative team research. Form voluntary cross-discipline teams to design detailed candidate experiments tailored to available hardware. These teams will consist of members of the science, engineering, and technology (hardware/software) development communities. The teams will develop near-term science for identified hardware items to ensure high-quality feasible research can be accommodated. This strategy recognizes two key workshop findings. The first is that successful space biology investigations will require sharing flight facilities across organizations. The second is that consortia of scientists collaborating on a multi-factor attack on research problems can yield a significantly higher quality and quantity of scientific information within the same manifest allocation.

2. Focused NASA Research Announcement (NRA) or Announcement of Opportunity (AO). The current NRA/AO approach, with engineering working to accommodate the proposed science, is inconsistent with the demands of the early ISS research environment. A focused AO or Dear Colleague letter would better direct investigators to propose experiments and observations that will be feasible within the capabilities of the current Shuttle/ISS environment. Researchers will be encouraged to establish cross-discipline research teams to propose a series of experiments optimally configured to accomplish high-quality collaborative research and produce associated publications. Time required for processing NRAs, as currently managed, may be counter to getting early science on board ISS. A more streamlined selection process is recommended.

3. Biosample/data sharing and archiving. Enable and encourage organism, tissue and data sharing within and between research teams through all phases of flight experiments. As part of the experiment designs, archive biosamples and data in a manner to facilitate sharing by researchers. Use cDNA libraries to share the data within the science community and increase the science return. Utilize bioinformatics, scientific visualization, and other computational enhancement expertise and resources within NASA, agencies that NASA collaborates with, and online systems shared by the research community. This strategy addresses the opportunity to significantly amplify the value of data obtained from a single space flight investigation and recognizes that the value of the data can increase over time if properly managed.

4. Information and tools for investigators. Conducting biological research in space is more akin to conducting field biology investigations than it is to conducting laboratory research. Further, the peculiarities of both the microgravity environment and the spacecraft demand approaches that are simply not used in any terrestrial laboratory. For these reasons, NASA should provide mentoring to assist new investigators through the complex ISS flight research process, as does the European Space Agency (ESA). For investigators to have a better understanding of the hardware available for research, NASA should collaborate with its international ISS partners to provide an online hardware catalogue profiling NASA, international partner, NASA-sponsored Centers for Commercial Development (CCDs), and commercial flight hardware vendor products. Copies of functional hardware should be made available to the research teams so that investigators can be familiar with hardware performance and organism life support capabilities in order to better propose and conduct effective experiments. This strategy was strongly endorsed by first time as well as experienced flight investigators. As part of this effort, there should be an early focus on developing a suite of common and shared procedures and tasks that will be used across all biological disciplines. This includes but is not limited to: cryopreservation, recovery from cryopreservation, sample storage on ISS, common databases for ISS that are available to the community of investigators, and state of the art approaches to the construction and performance of genomics and proteomics research in space.

6. Space Biology Research Institute. One way to establish an infrastructure to support implementation of these recommendations is to create a Space Biology Research Institute similar in concept to the Astrobiology Institute or the National Space Biomedical Research Institute, but smaller in scope. These institutes provide an essential research roadmap and science communications infrastructure that attracts high-quality university researchers and facilitates cross-disciplinary studies. A virtual institute could be established within the Fundamental Space Biology (FSB) Program Office based on a FSB web-based intranet which provides online access to information, resources similar to those provided by ESA's Virtual Campus for the ISS (http://www.spaceflight.esa.int/file.cfm?filename=utilvirtcamp).

B. Science

What Fundamental Space Biology science should be conducted on the Shuttle/ISS and how can it be accomplished?

1. High-priority research goals. Because the space environment (microgravity, increased radiation, closed environments) is unique for living systems, it can provide special insights into gene regulation, macromolecule, cell and organism functions as well as evolutionary processes. The initial focus will be on characterizing the molecular basis for life's adaptation to space. The Workshop participants recommend adding another tool to the space biology portfolio by implementing observational studies in areas newly opened by the biotechnology revolution, especially in: genomics, proteomics and molecular biology. These observational studies will be used to generate focused hypotheses to be tested in controlled experiments consistent with traditional space biology approaches. Research that can be done on early ISS should study the effects of the space environment on:

- Simple organisms whose full genome is known to support future integrated studies ranging from gene expression to metabolic/structural adaptation
- Selected well-characterized organisms for special studies on aging, infectivity, immune response, disease, and high-priority space medicine topics
  - Genetic changes and adaptations in organisms over multiple generations
  - Cells in culture—including variable gravity effects
  - Small plants to evaluate gravity sensing, long-term growth, and morphogenesis with environmental monitoring using microsensor systems
- Time course studies on all of the above.

2. Science planning and design. Conduct comprehensive ground-based studies to develop and verify experiments so that problems are solved before they fly. Experiments should be iterative: plan multiple experiment replicates over multiple flights to estimate measurement variability, solve problems, and build statistical power. Include many samples in each flight for greater statistical significance and better controls. Evaluate already approved experiments that no longer have a designated mission for potential accommodation on the early ISS. Take advantage of remarkable developments in miniaturization and automation to develop "Minuteman" investigations, which are passive self-contained science packages flown as opportunistic payloads. These allow NASA to take advantage of all flight opportunities. A number of the candidate species described below can remain dormant for months before flight, can be revived inflight, and can remain fixed and chilled for weeks after experiment termination. These species, which include those that pioneered the Human Genome Project, allow maximum flexibility in manifesting. They also provide results useful to the broadest science community.

3. Candidate organisms to study. The following are the best understood organisms on Earth and are routinely used by molecular biologists to work out fundamental processes for application to more complex problems. The species also provide the means to carry out the SSB recommendation to study life at all levels of biological organization.

- Human and mammalian cell and tissue cultures – space medicine issues, complexity, integration of space flight effects from cells to tissues.
- Bacteria (e.g., *E. coli*) – basic biochemical pathways underlying other complex cell processes; infectivity, virulence, vaccine development.
- Yeast (*Saccharyomyces cerevisiae*) – DNA replication, transcription, RNA processing, protein function, cell division, organelle function, signal transduction
- Micro-Plants (*Arabidopsis thaliana*) – plant genetics, gene expression studies
- Nematode (*C. elegans*) – microscopic studies of origin and lineage of cell development to study mutations
- Insects (*Drosophila melanogaster*) – multi-generation, neurobiology studies
- Humans as incubators - flora and fauna evolution over time

C. Technology

What technology and hardware is available to support space biology on early ISS?

1. Hardware Approach. The recommended strategy includes the following:

- Use existing hardware to reduce cost and development time. Provide funding for replication of key hardware and for small but important modifications that amplify yield and quality.
- Create a cell biology suite on Space Station by combining several hardware elements: incubators, automated fixation systems, imaging systems, centrifuges, freezers, glove boxes, microscope systems. Keep hardware resident on ISS and bring up new experiments for efficiency of space, crew time requirements, and cost.
- Conduct ground baseline studies to characterize hardware performance, biocompatibility, data acquisition/processing for candidate flight systems, and establish baseline data for control variables such as launch and landing stresses. This should begin as soon as possible, ideally during the summer 2002.

2. Capabilities (+=available now; = could be available over next 5 years; - partial capability could be available). Specific hardware capabilities needed include:

+ Incubators with automated sample preservation capability and the ability to take time course measurements.
  Small, variable gravity centrifuges (1-g controls important, but fractional-g may be even more so)
- Improved preservation of specimens given current limitations of ISS: support development of freezers (-80 and –180 °C), critical for returning valid specimens; custom containers that efficiently use freezer space
  Support development of NASA Glenn Research Center (GRC) microscope for living cells
- Continuous sampling of environmental variables with download of data
  Insect habitat essential for multi-generational studies
  Modify some hardware components to increase the number of samples flown

3. Technologies. Use the following enabling technologies to support and advance space biology on ISS:

- Biotechnologies applicable to space flight such as gene expression arrays, proteomics tools, bioinformatics, 4-D visualization, fluorescent probes
- Advanced sample preservation for inflight sampling and transport to ground
- Miniaturized sensor systems
- For postflight data analysis and sharing, apply bioinformatics tools and develop facilities within NASA; use cDNA libraries; 3-D reconstruction for modeling and simulations; sample bank.

D. Societal Benefits

How to identify, capture, and communicate the anticipated and actual benefits from this research?

Over the past thirty years, biological responses in space have tantalized researchers with the potential to obtain important insights about aging, new pharmaceuticals, and basic biological processes. Until now, however, there were few opportunities to confirm the promise of space biosciences research. The precision of current molecular biology techniques allows definitive comparisons between space effects and ground based biological issues and will allow researchers to validate the use of space for humanitarian benefits on Earth.

1. Identify benefits. Include a category in all research proposals for anticipated benefits and assign definition of benefits task to each collaborative research team. NASA support staff will track these anticipated benefits by research topic.

2. Capture benefits. Ensure that individual researchers and teams profile emerging benefits from their research beginning with ground studies. Collect benefits in a web database for use by NASA, Public Affairs, contractors and others to educate all staff and format benefits for sharing with public.

3. Communicate benefits. Provide online access to benefits to NASA/contractor staff and the public. Restate on a regular basis the value of the work to the public and to congress whenever the opportunity arises. Include communicating the value in relation to the cost of doing the science as a key part of the story.

Conclusion:

Very different futures are available to a species that can thrive beyond its planet of origin versus those whose destinies are constrained to a single world.

Exciting essential pioneering science can be conducted during the early Space Station era by bringing the biotech revolution to space and space biology samples to the biotech revolution. The biotech, infotech, and nanotech revolutions are still accelerating rapidly and continue to create unanticipated opportunities for discovery. NASA must be vigilant in harvesting technology advances to maximize science return from space and swift in applying them. Most of all, NASA must collaborate with a wide number of organizations that offer solutions to key problems and be agile enough to employ those solutions.

Using a "fix, freeze, and return" mode for early biological investigations, NASA can provide a "sample return" program for space biological sciences. Because analyses are conducted postflight, the newest and best techniques can always be applied.

New technologies open new discovery domains for space biosciences. Because these new domains have never been explored, observational science is an important and valid tool to complement traditional single PI/single hypothesis science. There are flight opportunities in the "nooks and crannies" around traditionally selected research that further amplify data yield. These should be used to their fullest potential.

A number of techniques can and should be applied postflight to further amplify data yield. Funds should be provided for bioinformatics, cDNA libraries, data-mining, cross organizational investigations, and integrative studies that synthesize results across a number of approaches, species, flights, and systems.

A new investigator community expert in cell and molecular biology is needed to conduct research during the early Space Station era. However, new investigators often view research in space as a microgravity version of their university laboratories and propose accordingly. The constraints of the early Space Station demand an implementation approach more akin to field biology in remote hostile environments where research ambitions are constrained by the equipment that the scientists can carry on their backs. The mismatch of expectation and reality yields proposals that garner high points for science but are impractical to implement. New solicitation mechanisms that match high quality discovery potential with ease of implementation should be a management priority, especially during the next five years.

Workshop participants revealed significant opportunities for discoveries that may be medically important and commercially interesting. At the least, these studies will provide a biological narrative of how the only life that we have ever known adapts to regions beyond its home planet. It is a historic opportunity.

Appendix B: Workshop Agenda

SPACE BIOLOGY ON THE EARLY INTERNATIONAL SPACE STATION

Thursday, March 14, 2002

9:00 **Welcome**
Dr. Henry McDonald
Center Director, NASA Ames Research Center

9:10 **Workshop Goals**
Dr. Baruch S. Blumberg, Nobel Laureate,
Director, NASA Astrobiology Institute

9:20 **Introduction to Space Biology Over the Next 5 Years**
Dr. Maurice M. Averner
Program Manager, NASA Fundamental Space Biology Program

9:30 **NASA Advisory Committees' Key Questions and Recommendations**
Dr. Kenneth M. Baldwin
Advisory Committee
Dr. Kenneth Baldwin
Dr. Danny Riley
Dr. Gerald Sonnenfeld
Dr. Lawrence DeLucas
Dr. Herman Vandenburgh
Dr. J. Milburn Jessup

10:00 **ISS Research - Chief Scientist Perspective**
Dr. Roger Crouch
ISS Chief Scientist

10:15 **Break**

10:30 **Crew Interests and Opportunities**
Dr. Yvonne Cagle
Astronaut Mission Specialist

11:00 **Available Hardware**
Orbital Technologies Corporation (ORBITEC), BioServe, Space Hardware Optimization Technology Inc. (SHOT), Wisconsin Center for Space Automation and Robitics (WCSAR), Oceaneering Space & Thermal Systems, Inc., Kennedy Space Center Biological Research in Canisters (KSC-BRIC), NASA Glenn Research Center Microscopes

12:30 **Working Lunch**

1:00 **Biotechnologies Applicable to Space Research**

Analyses:

Gene Expression	-E. Kerr, Affymetrix
Proteomics	-T. Hammond, Tulane
Fluorescent Probes	-E. Almeida, ARC
Transgenics	-S. Reinsch, ARC

Inflight Protocols

Sample Preservation	-T. Goodwin, JSC
Miniature Sensors	-J. Hines, ARC
JSC – ISS Issues	-N. Penley, JSC

Post-flight Data Application

Bioinformatics	- A. Pohorille, ARC
cDNA Library	- E. Wang, Louisville
3-D Reconstruction	- R. Boyle, ARC

4:00 **What Strategies should NASA Consider for Understanding the Response of Life to Space Over the Next 5 Years? Key questions and techniques.**

General Discussion
Ms. Lynn D. Harper, Lead, Integrative Studies

6:00 **Working Social hour and buffet 240A**
Building 244 Centrifuge Accommodations Module Mockup Tour
Building 240A Flight Hardware Display

Friday March 15, 2002

7:30-8:30 **Continental Breakfast**

8:30-9:30 **Conducting Research on the International Space Station between 2002 and 2007**

Ms. Bonnie P. Dalton
Chief (Acting), Life Sciences Division,
NASA Ames Research Center

Dr. Gary C. Jahns, Fundamental Space Biology Program Office
Deputy for Flight Programs

Dr. Neal R. Pellis
Director, Cell Research, NASA Johnson Space Center

Preflight protocols, transfer protocols between shuttle and station, space station inflight conditions, astronaut activities, experiment termination and storage, return to Earth protocols, critical issues and challenges

9:30-11:30 **Working Groups** **(Break as Needed)**

<u>No Power Up</u>
<u>Power Up</u>
<u>Problem Solving</u>
<u>Societal</u>

11:30-11:45 **Group Wrap Up for Presentation**

11:45-12:30 **Group Presentations – 8 Groups**

12:30-1:00 **Working Lunch**

1:00-2:45 **Group Presentations** (continued) **– 8 Groups**

2:45-3:45 **Discipline Working Groups**

<u>Science Strategies</u>: Species Size, Complexity, Multigeneration, Developmental Biology, Comparative Biology, Evolutionary, Studies Relevant to Space and Earth Medicine

<u>Implementation Approaches</u>: Pros and Cons among Competitive Peer Reviewed Studies, Focused Research, Systems Biology, Opportunistic Research, Observational Science, Hypothesis Driven Research

<u>International Space Station Constraints and Hardware Problem Solving</u>: Flexibility in Station Accommodations and Constraints, Solutions from Advanced Technologies to meet Highest Priority Science needs

<u>Value to Science and Society</u>

4:00-4:30 **Summary** Drs. Blumberg and Baldwin

What will this Body of Work Teach Us? What is its Value to Science and Society?

Appendix C: List of Attendees

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